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DTC Developmental Testbed Center

Evaluation of New Analyses and Methods for Verification of Cloud Predictions

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National Center for Atmospheric Research

Motivation and Goals

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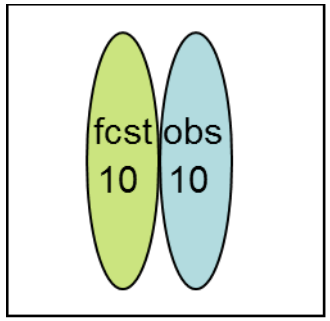
- Motivation
  - Clouds have important impacts on activities of the US Air Force and are a prime focus of the 557th Weather Wing
  - Skill of cloud forecasts impacts decision making (e.g., uncertainty in cloud cover predictions can change operational decisions)
- Goals
  - *Long-term*: Create a meaningful cloud verification "index"
  - *Short-term*: Identify useful components of such an index

Approach

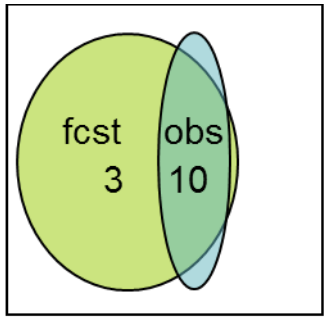
1. **Standard methods** based on traditional metrics (continuous, categorical)
2. Investigate **object-based and distance metrics** to provide forecast quality information that
   - Provides diagnostic, user-relevant information
   - Includes methods not subject to "hazards" of traditional verification (e.g., "Double Penalty")

Initial focus on CONUS, fractional coverage (TCA = Total Cloud Amount)

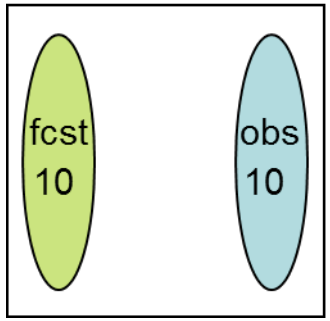
Secondary: Global forecasts, ARM observations



Hi res forecast
RMS ~ 4.7
POD=0, FAR=1
TS=0



Low res forecast
RMS ~ 2.7
POD~1, FAR~0.7
TS~0.3



Observations, Analyses, and Forecasts

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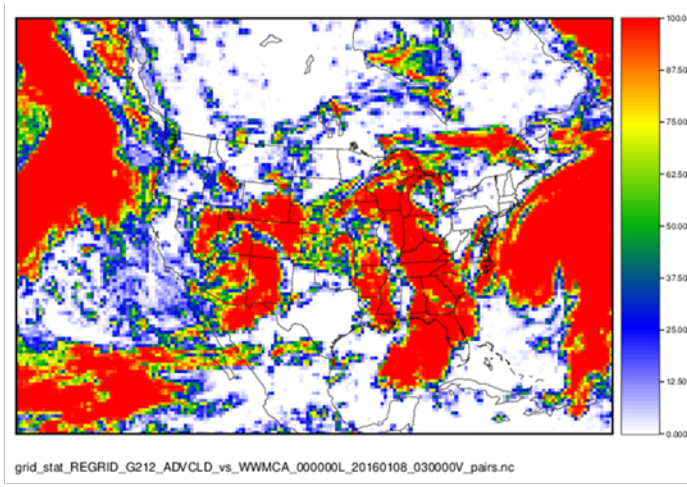
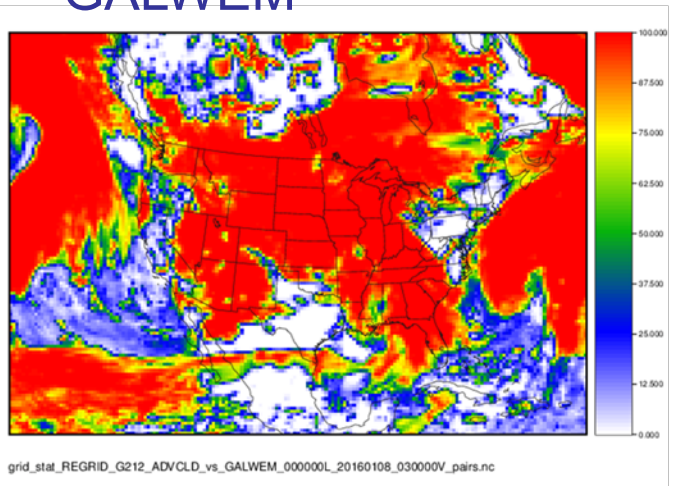
- **"Observations" and Analyses**
  - METARs (but not shown here)
  - WWMCA (gridded World-Wide Merged Cloud Analysis)
  - WWMCA-R (WWMCA updated in post-analysis with all obs available)
  - ARM site Total Cloud Amount (TCA) for 4 locations
- **Forecasts**
  - 2 global models (72 h)
    - **GALWEM** (AF implementation of UK Unified Model)
    - **GFS** (NCEP Global Forecast System)
  - **DCF** (Diagnostic Cloud Forecast)
    - Bias-corrected GALWEM and GFS
  - **ADVCLD**: Advection (persistence) model (9 h)
- Sample data for 4 seasons (1 week each)
- NCEP grid 212 (polar stereographic; 40 km)
- Model Evaluation Tools (MET) and Spatial-Vx R package used for all analyses

WWMCA



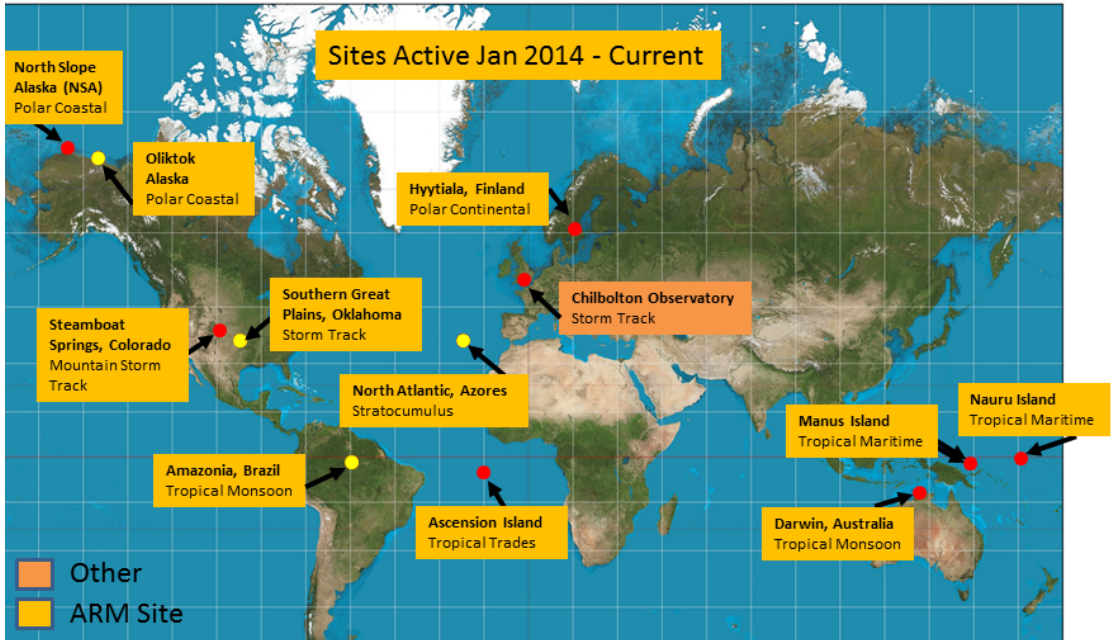
GALWEM



Conclusions First…

- **Continuous methods** (RMSE, MAE, etc.) do not provide much useful information regarding TCA performance – primarily due to discontinuous nature of clouds
  - Edges
  - Tendency of products toward 0 or 100% values
- **Point observations are less useful overall than satellite-based analyses due to limited availability globally**
- **Categorical methods** (POD, FAR, etc.) are more useful for answering relevant questions about cloud occurrence
  - Especially when presented in a diagnostic multivariate form
- **Object-based methods** have promise of providing useful information – when configured appropriately
- **Distance metrics** can provide interesting diagnostic information – but need to be explored more

ARM sites

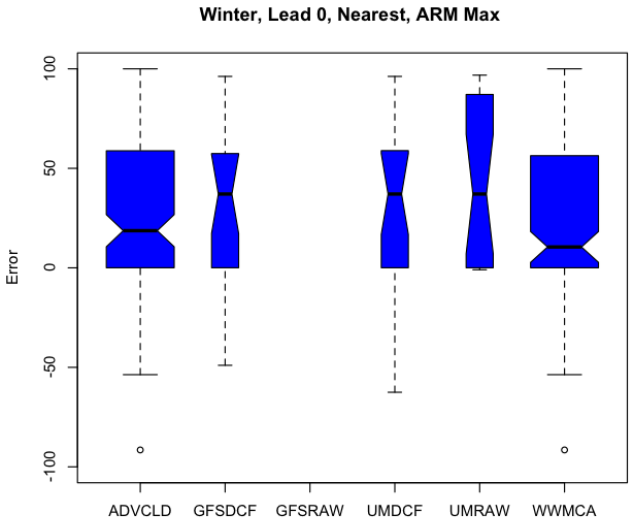


Cloud amount measurements from Total Sky Imager used for the evaluations

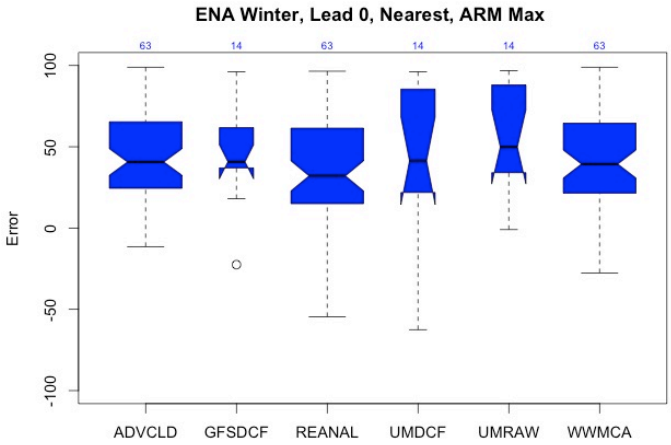
Limited ARM data obtained for 4 ARM sites during our 4 periods

- Oliktok, Alaska (OLI)
- Southern Great Plains, Oklahoma (SGP)
- North Atlantic, Azores (ENA)
- Amazonias, Brazil (MAO)

Example ARM comparisons



4 ARM stations
Winter
Lead=0



ENA (Azores)
Winter
Lead=0

Errors vary by

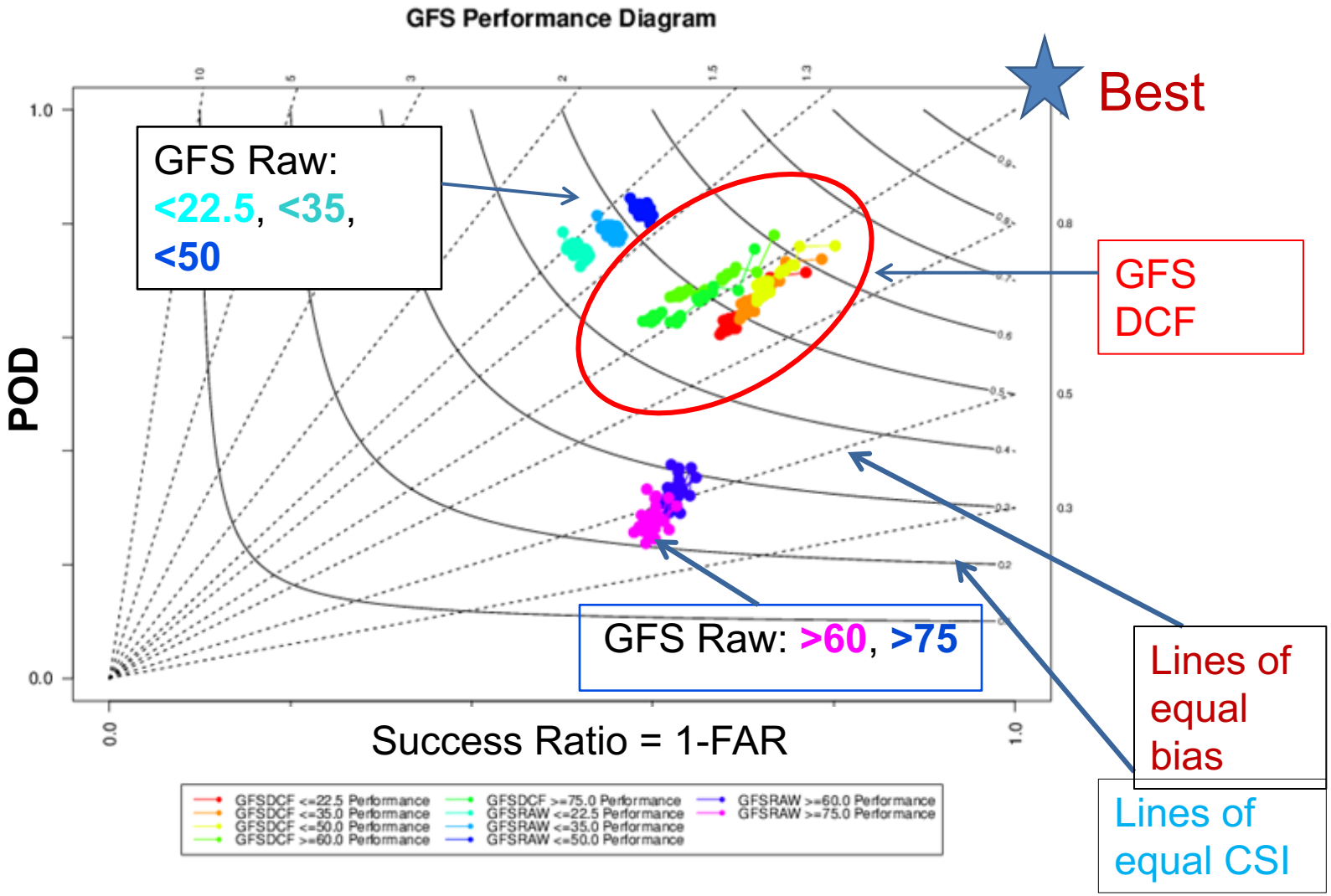
- Location
- Matching approach (e.g., Max vs. Average)
- Neighborhood size (e.g., nearest, 9, 16 gridpoints, etc.)

Although active sensors should be the “best” datasets for comparison, limitations in data availability limit their potential usefulness

- Difficult to combine results across locations

Gridded comparisons: Categorical statistics

Performance Diagrams using WWMCA-R as the verification grid



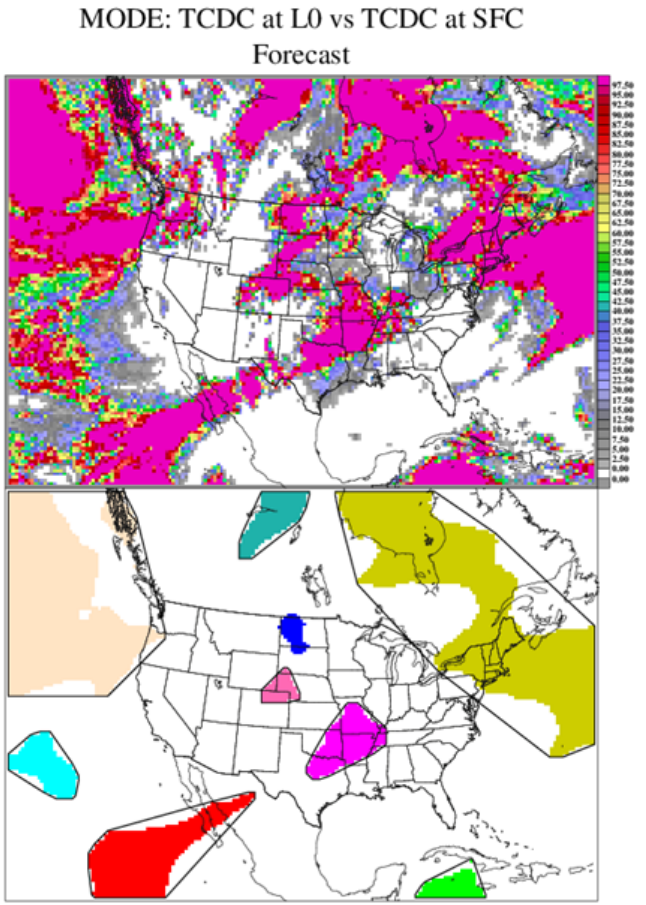
After Roebber (2009)

MODE Object-Based Approach

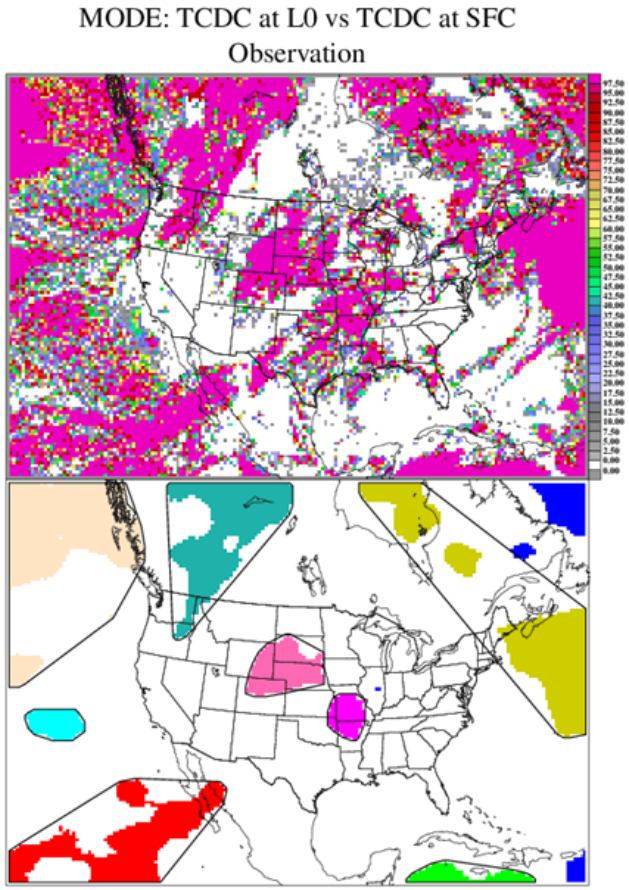
MODE in a nutshell:

- Identify objects
- Measure and compare object "attributes" (e.g., size, location, intensity)

GALWEM

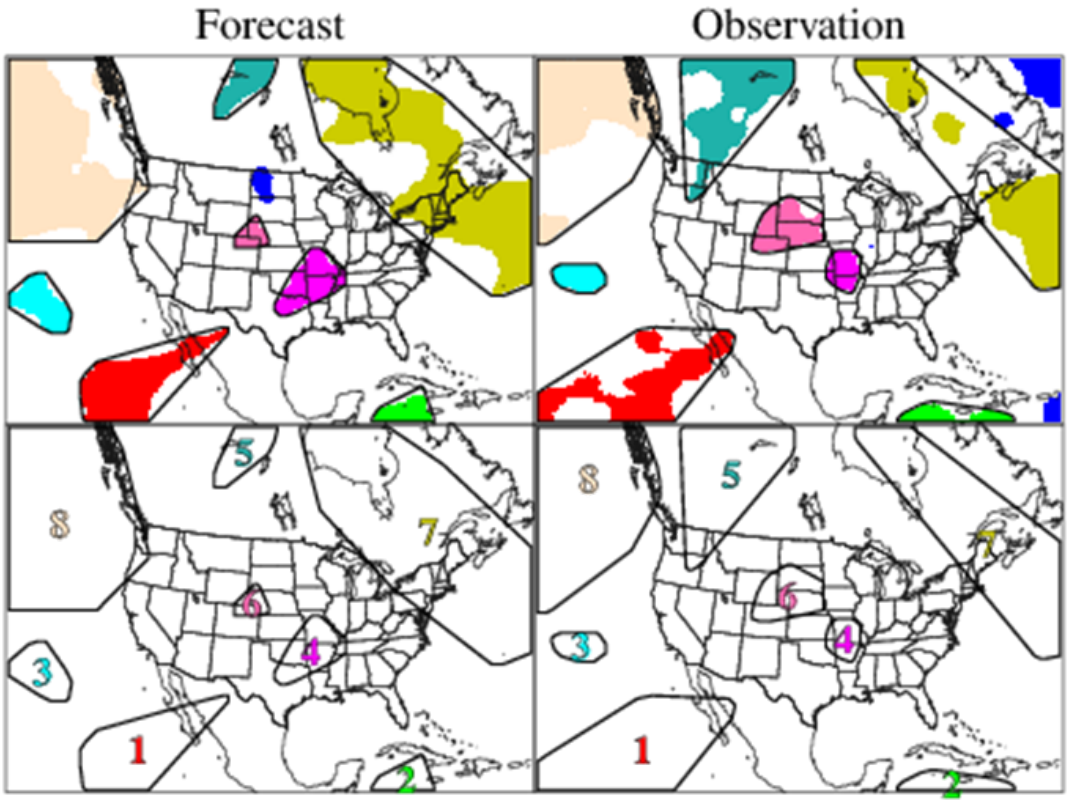


WWMCA



11 November 2015
Cloudy Threshold (TCA > 75)

Cluster Object Information

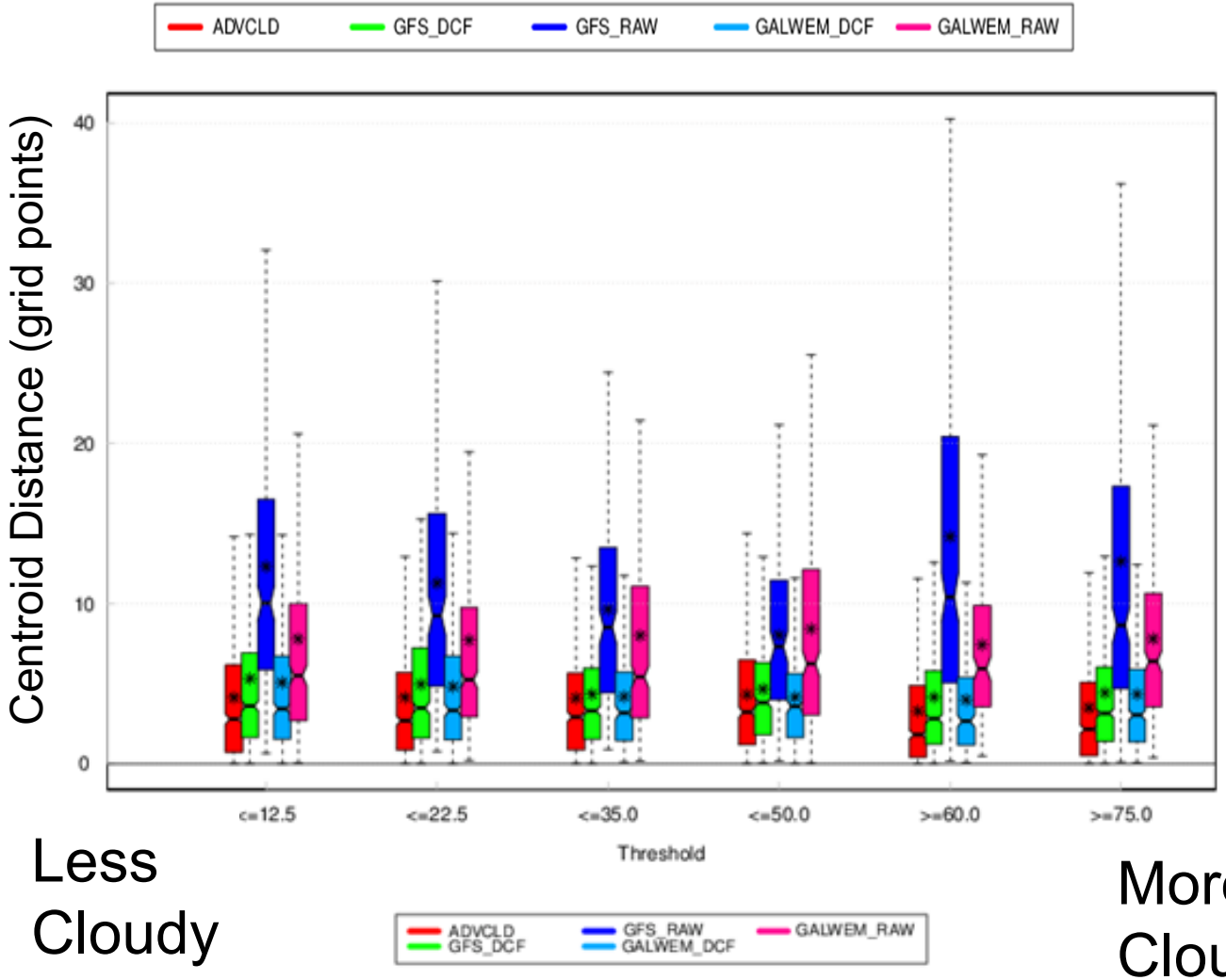


- Some displacement of all clusters
- Large area differences, for some objects

… Etc.

CLUS PAIR	CEN DIST	ANG DIFF	FCST AREA	OBS AREA	INTER AREA	UNION AREA	SYMM DIFF	FCST INT 50	OBS INT 50	FCST INT 90	OBS INT 90	TOT INTR
1	8.53	10.08	689	816	504	1001	497	100.00	100.00	100.00	100.00	1.0000
2	6.18	10.69	131	138	87	182	95	100.00	100.00	100.00	100.00	1.0000
3	9.80	35.64	247	145	33	359	326	89.00	100.00	100.00	100.00	0.9411
4	4.69	51.94	299	130	121	308	187	100.00	100.00	100.00	100.00	0.9158
5	16.56	13.02	229	829	196	862	666	100.00	100.00	100.00	100.00	0.9018
6	3.47	19.33	81	305	81	305	224	100.00	100.00	100.00	100.00	0.8958
7	11.74	2.27	2366	1049	1001	2414	1413	100.00	100.00	100.00	100.00	0.9407
8	15.77	38.71	1921	1157	773	2305	1532	100.00	100.00	100.00	100.00	0.9607

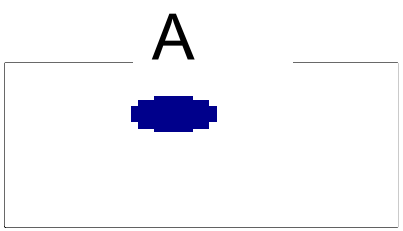
Example MODE summary result: Centroid Distance

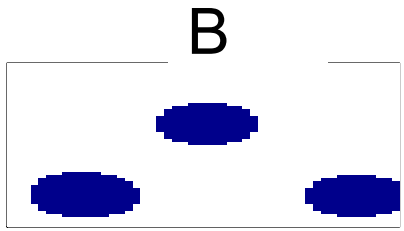


Less Cloudy

More Cloudy

Distance Map Measures

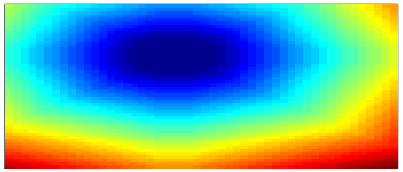


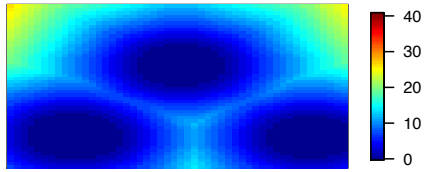


Distance map of A

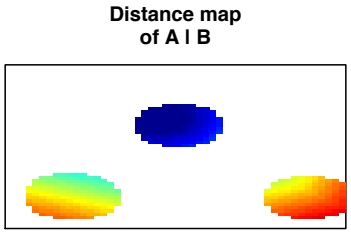
Distance map of B

d(x, A)

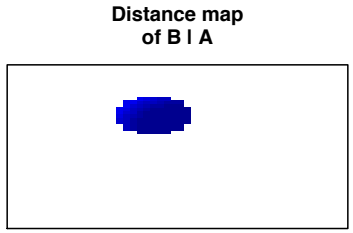




d(x, B)



d(x, A | B)

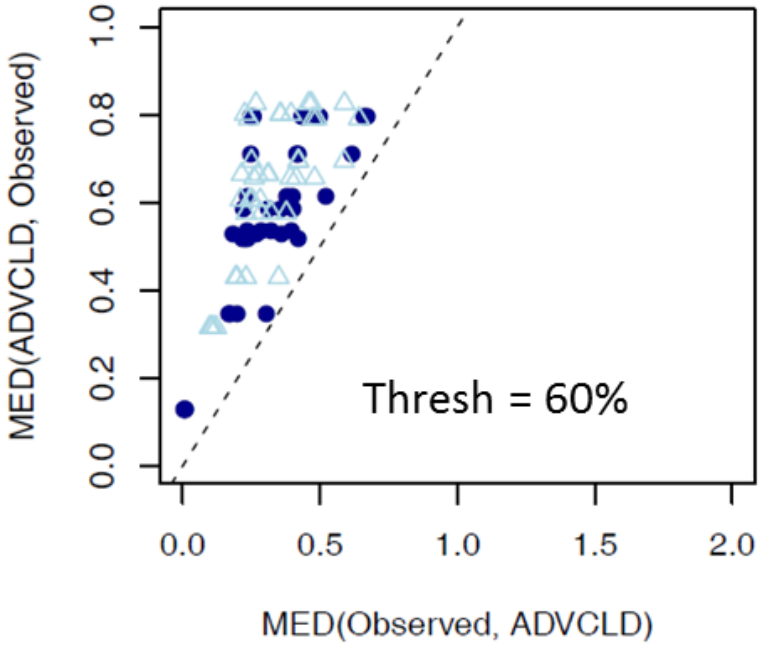


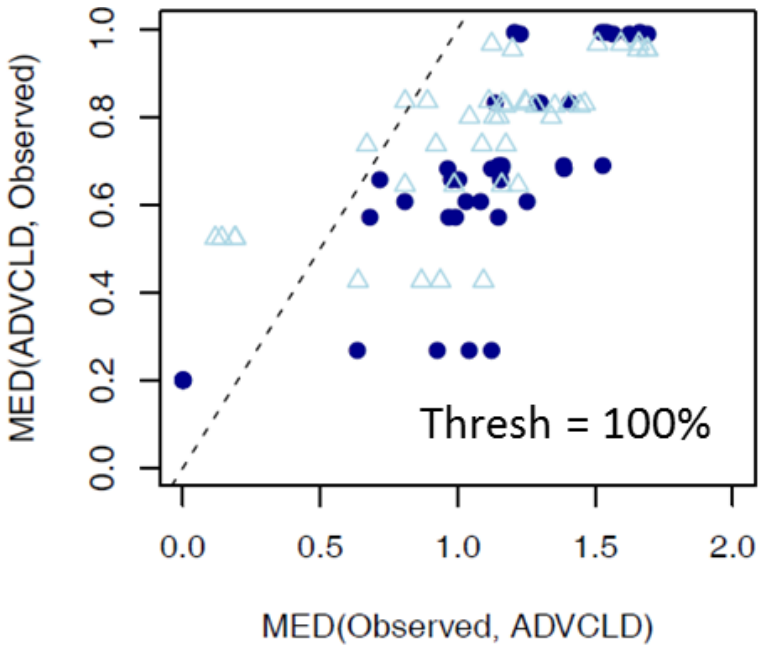
d(x, B | A)

MED(A, B) = $\Sigma_{\mathbf{s}\ \text{in}\ D}\ d(x, A \mid B) / N$,

s are locations in the domain, D, and N the total number of grid cells.

Mean Error Distance





Examine average error distance from all forecast points to the nearest obs point [**MED(forecast, obs)**], and from all obs points to the nearest forecast point [**MED(obs, forecast)**]

- Above diagonal: Misses
- Below diagonal: False alarms

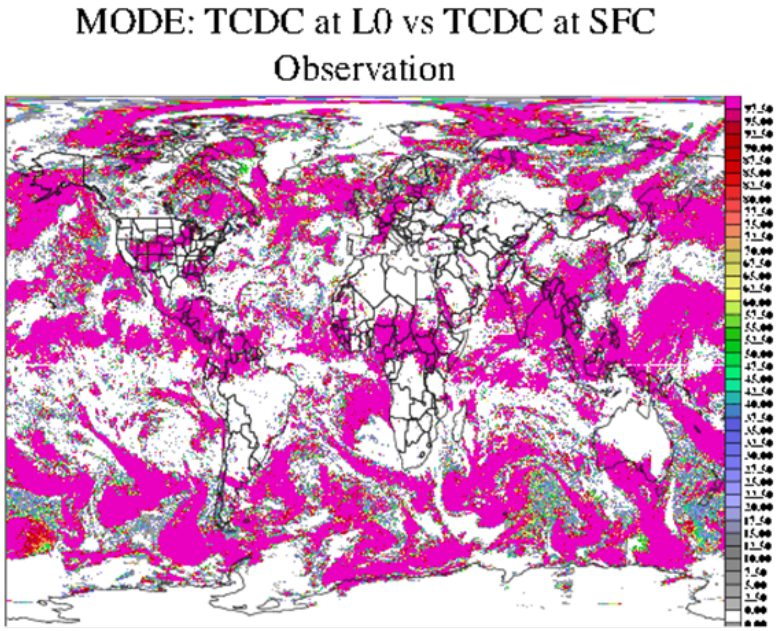
Gilleland 2017 (WAF)

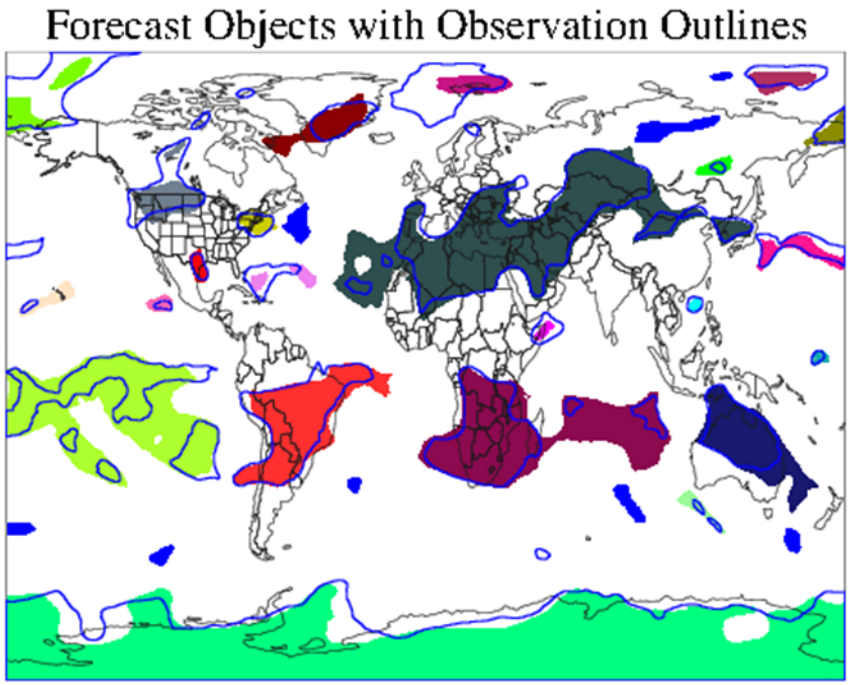
Other promising approaches:

- **Hausdorff and Baddeley Delta metrics**
- **Image warping**
- **Geometric measures**

Conclusions

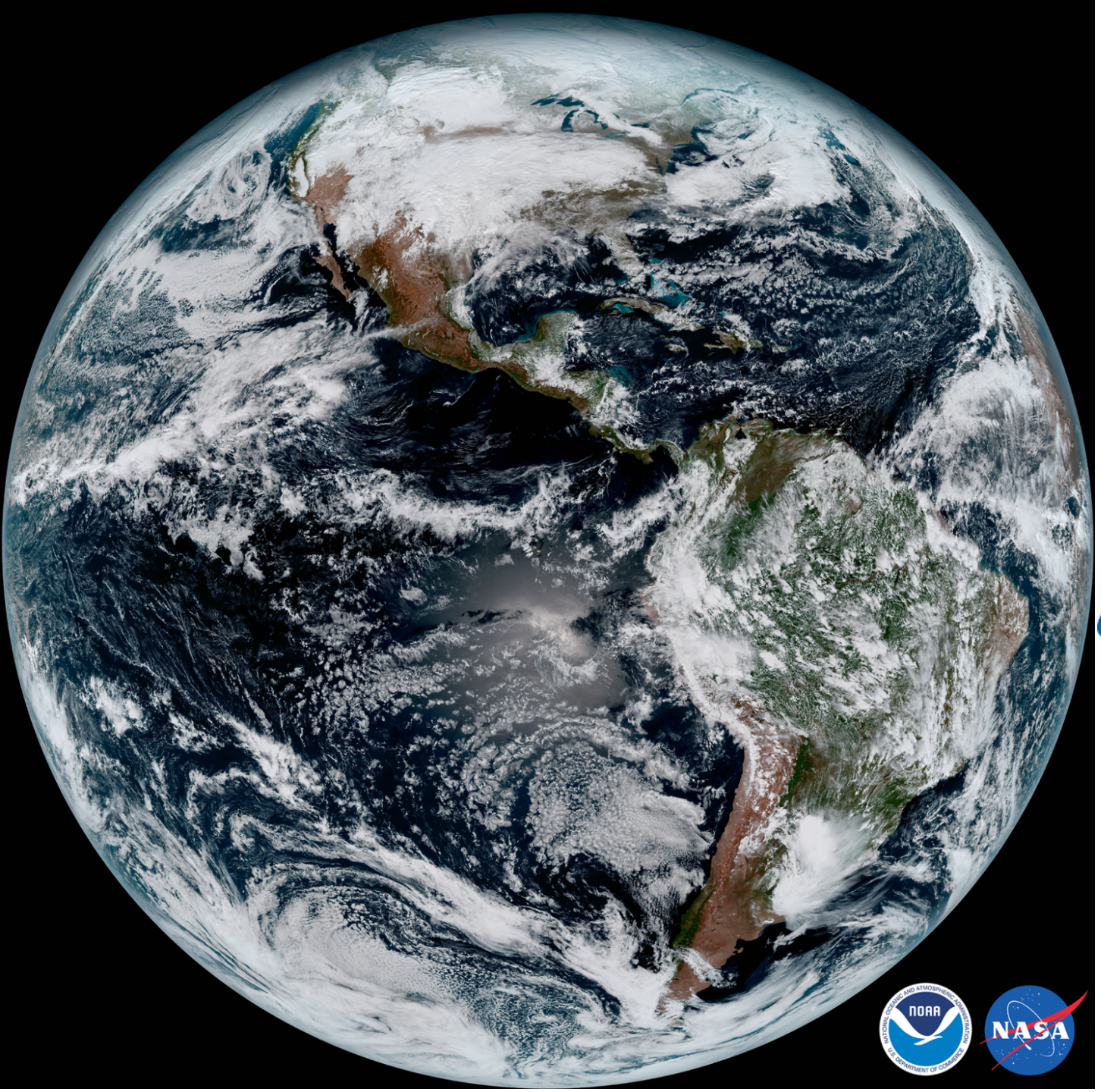
- Categorical methods are the most useful "traditional" approach for evaluating TCA
  - Diagnostic plots (box plots, performance diagrams aid in interpretation of results)
- Spatial and distance metrics have a lot of benefits and are promising approaches
- On a global scale, MODE is especially useful for *evaluation of non-cloudy areas*





Future Work

- Further *tests of distance and geometric methods*, and other *spatial approaches*
- Evaluation methods for *bases, tops, layers, and other user-relevant variables*
- Use of additional *active sensors*
- Take into account some aspects of *observational uncertainty* – e.g., pixel age



Thank You

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Geometric Approach

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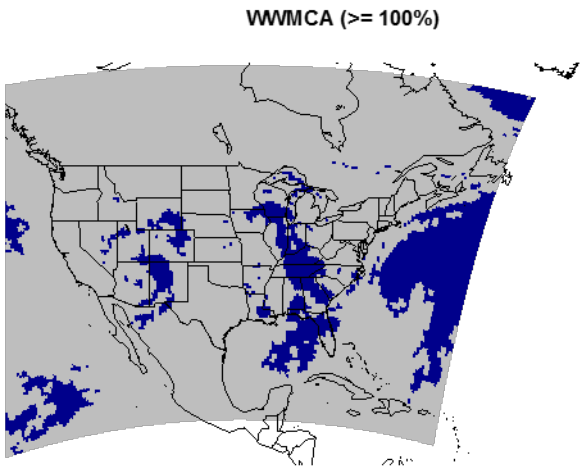
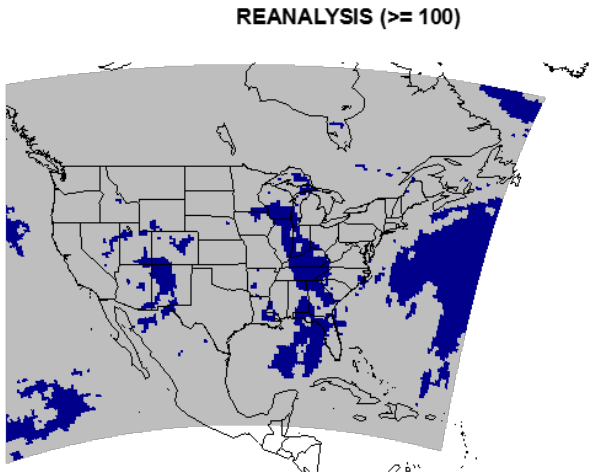
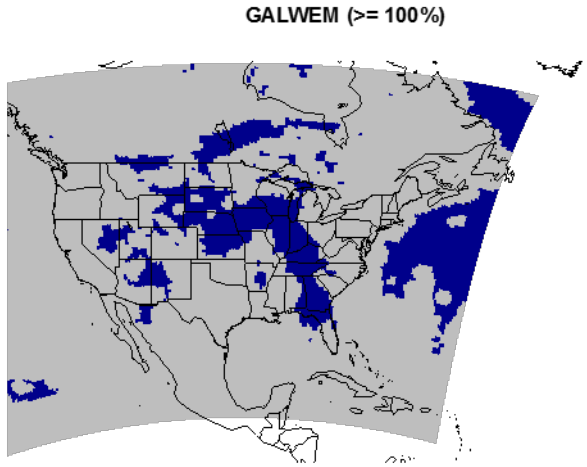
Measure and compare Geometric characteristics of objects/areas: Connectivity (C), Shape (S), Area (A) (AghaKouchak et al. 2010; *J. Hydromet*)







	WWMCA-R	WWMCA	GALWEM
C_{index}	0.674	0.713	0.801
S_{index}	0.398	0.408	0.436
A_{index}	0.173	0.180	0.216